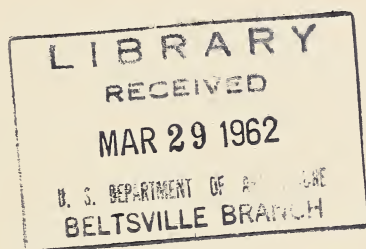


Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A281.9
Ag 8
56

Relationship of Soil Moisture and Precipitation to Spring Wheat Yields in the Northern Great Plains



Production Research Report No. 56

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

In cooperation with the
Montana, North Dakota, and South Dakota Agricultural
Experiment Stations

CONTENTS

	Page
Review of literature	1
Data available and procedure of interpretation	2
Results and discussion	5
Summary	14
Literature cited	15
Appendix	16



Growth Through Agricultural Progress

Washington, D.C.

Issued February, 1962

Relationship of Soil Moisture and Precipitation to Spring Wheat Yields in the Northern Great Plains¹

By J. R. THOMAS, soil scientist, T. J. ARMY, soil scientist, Soil and Water Conservation Research Division, and E. L. COX, biometrician, Biometrical Services, Agricultural Research Service

Lack of moisture is a major factor in limiting spring wheat production in the northern Great Plains. Cultural practices have been devised and advocated to conserve moisture and to increase the efficiency of moisture use by the wheat plant. A summer fallow period to increase soil moisture reserves for the next crop has been used in the more arid sections of the Great Plains since the beginning of the 20th century. However, the practice of summer fallow only became widespread during the drought of the thirties. It has been estimated that 17.9 million acres were fallowed in the 10 Great Plains States (9)² in 1951. Many studies have indicated that the practice of fallowing materially reduces the frequency of crop failures and provides a partial stability to dryland farming operations.

The primary objective of this study was to evaluate the importance of soil moisture supply at seeding and of preseasonal and growing season precipitation on the yield of spring wheat grown on important soil types in the northern Great Plains. The study includes and evaluates the effect of two cultural practices: (1) Alternate wheat and fallow and (2) continuous cropping.

REVIEW OF LITERATURE

Fallowing is expected to increase available soil moisture. Because of the success of fallowing practices, many workers have become interested in investigating the importance of soil moisture at seeding time and the effect of growing season precipitation on wheat yields.

Cole (3) investigated the dependence of spring wheat yields on annual precipitation (calculated for a year ending July 31) at 14 locations in the northern Plains. From the data he used, the varia-

¹ Joint contribution from Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Agricultural Experiment Stations of Montana, North Dakota, and South Dakota.

² Italic numbers in parentheses refer to Literature Cited, p. 15.

bility in yield was reduced by an estimated 61 percent after being expressed as a function of annual precipitation. Similar relationships were obtained by Aasheim³ by expressing grain yields as a function of spring-to-harvest precipitation. Pengra (8) could show only that wheat yields were significantly related to precipitation in those areas of South Dakota receiving less than 11 inches during the growing season. He stated that preseasonal precipitation was almost as effective as seasonal precipitation in influencing small-grain production.

Smaller coefficients of determinations (r^2) for wheat yields and for precipitation on summer fallow than on continuous cropping (1, 3, 6) suggest that factors other than precipitation have greater influence when cultural methods are used that increase the supply of soil moisture at seeding time. Cole and Mathews (4) showed that expressing the yield of spring wheat as a function of the depth to which the soil was moist at seeding time was tenable. However, Aasheim³ found that soil moisture on both fallowed and continuously cropped land accounted for less than 24 percent of the variability in yield of wheat at Havre, Mont. Similar results have been reported by Army and Hanson (1) for spring wheat production at three locations in Montana. However, Thysell (11) found a significant relationship between spring wheat yields and soil moisture at seeding on continuously cropped spring-plowed land ($r^2=0.26$) but not on fallowed land ($r^2=0.04$). Soil moisture is believed by some to be of greater importance in the southern Plains; for example, Finnell (5) states that "soil moisture at planting time is the most important measurable factor that will affect the success of a wheat crop."

Great seasonal variability of rainfall and excessively high and low temperatures are characteristic of the northern Great Plains (12). Average annual precipitation ranges from 11 to 16 inches, with approximately three-fourths of the annual precipitation occurring from April through September. June is normally the wettest month, followed closely by May and July. Temperatures over 100° F. and below 0° are not uncommon during any year.

DATA AVAILABLE AND PROCEDURE OF INTERPRETATION

Climatic, soil moisture, and yield data have been recorded in conjunction with studies on the effects of different methods of cropping and tillage on production of spring wheat at various experiment

³ AASHEIM, T. S. INTERRELATIONSHIPS OF PRECIPITATION, SOIL MOISTURE AND SPRING WHEAT PRODUCTION IN NORTHERN MONTANA. Unpublished M.S. Thesis, Montana State College. 1954.

stations in the northern Great Plains (2). Three methods of cultivation with spring wheat were examined: (1) Spring-plowed land, continuously cropped; (2) fall-plowed land, continuously cropped; and (3) alternate crop and fallow. Treatments were not replicated, but a crop was harvested every year.

The designations and locations of the stations selected for study and the years for which yield and precipitation data were available are shown in table 1. Place names are used to designate the experiment station. Incomplete soil moisture records limited the available data to 17 years at Ardmore, 22 years at Dickinson, 31 years at Havre, and 34 years at Huntley.

TABLE 1.—*Designation and location of experiment stations selected for study and years of record*

Designation	Location	Years of record
United States Dryland Field Station-----	Ardmore, S. Dak-----	1913-32
Newell Irrigation and Dryland Field Station.	Newell, S. Dak-----	1909-55
Dickinson Substation-----	Dickinson, N. Dak----	1907-57
North Montana Branch Station-----	Havre, Mont-----	1907-47
Huntley Branch Station-----	Huntley, Mont-----	1913-46

Soil series and texture and the depth to which soil moisture calculations were made at each location are presented in table 2. Soil samples for moisture determination were taken at 1-foot intervals to a depth of 3 or 4 feet at or near seeding time. Percentage of moisture was converted to inches of water by means of previously determined volume weights.⁴ Four soil samples were obtained in each 0.1-acre plot.

TABLE 2.—*Soil identification and depth of soil sampling at each experiment station*

Location	Soil series	Texture	Depth of sampling
			<i>Feet</i>
Ardmore-----	Rosebud-----	Clay loam-----	4
Newell-----	Pierre-----	Clay-----	3
Dickinson-----	Morton-----	Loam-----	3
Havre-----	Joplin-----	Clay loam-----	4
Huntley-----	Nunn ¹ -----	do-----	4

¹ Field name used in 1960, subject to final correlation.

⁴ Unpublished records from the former Division of Dryland Agriculture.

Average grain yields at each location are shown in table 3. Complete precipitation, yield, and soil moisture data are given in appendix tables 11 to 20, inclusive. Yields were expressed in terms of bushels of grain per acre. All yield data were used, even though in some years crop failure was owing to causes other than lack of moisture. Spring wheat yield data from continuously cropped spring-plowed land were selected for study, except at Newell. Since yields of all crops at Newell were greater on fall-plowed land (7), fall-plowed continuously cropped wheat data were used for this location. Salmon and coworkers (9) have pointed out that spring-plowed continuous wheat has generally given highest yields in the northern Plains.

TABLE 3.—*Effect of cultural practices on mean spring wheat yields at the locations selected for study*

Location	Continuously cropped	Alternate crop and fallow
	<i>Bushels per acre</i>	<i>Bushels per acre</i>
Ardmore.....	11. 8	17. 2
Newell.....	¹ 13. 0	21. 2
Dickinson.....	12. 0	19. 1
Havre.....	7. 8	15. 8
Huntley.....	8. 3	13. 9

¹ Fall-plowed, others spring-plowed.

Since dates of seeding and harvest were found to be fairly constant, mean dates of seeding and harvest were used for each location. These dates were altered to conform with the nearest climatological week of the U.S. Weather Bureau (table 4). Seasonal precipitation was calculated for periods corresponding to climatological weeks.

TABLE 4.—*Average dates of seeding and harvest and corresponding climatological weeks at each location*

Location	Average dates of—		Climatological week No. ¹
	Seeding	Harvest	
Ardmore.....	Apr. 5	Aug. 1	6-22
Newell.....	Apr. 16	July 31	7-22
Dickinson.....	Apr. 14	Aug. 5	7-23
Havre.....	Apr. 25	Aug. 2	8-22
Huntley.....	Apr. 18	July 27	7-22

¹ Climatological week No. 1 is March 1-7, inclusive.

Simple and multiple regression and correlation techniques (10) were employed to study the effects of soil-moisture supply at seeding and precipitation on spring wheat yields.

RESULTS AND DISCUSSION

An indication of the importance of stored soil moisture at seeding time may be gained by describing yield as a linear function of stored soil moisture and by investigating the estimated regression coefficients and standard errors that arise from least squares calculations. Regression equations for five locations separately for the two cultural practices and combined are shown in table 5.

Soil moisture reserves provided a significant contribution to yield except at Dickinson. Coefficients of determinations ranged in value from 1.3 to 34 percent, which indicated that soil moisture at best accounted for only a small part of the yield variability. The fact that the regression coefficients under different cultural practices were not significantly different at any location provided the basis for the combined regressions. Despite the failure of the tests, the coefficients for the fallow treatments are, ignoring Dickinson, greater than the continuous cropping coefficients for the four locations. This suggests that the greatest change in yield for a given change in soil moisture occurred on fallowed land.

When grain yields are considered as a function of seasonal precipitation, the regression of yield on seasonal precipitation expressed in coefficient of determination form shows that 11 to 73 percent of the yield variance was associated with the variability in seasonal precipitation. The contribution of seasonal precipitation to yield was least well defined at Dickinson. The regressions for both cultural practices separately and combined as well as associated descriptive statistics are shown in table 6. The combined regressions for soil moisture were constructed because of lack of difference between the individual regressions.

The degree of effectiveness in expressing crop yields as a function of rainfall appears to depend on the particular calendar period over which the observations are made. Haas and Evans (6), in a study of the effect of annual precipitation on yields of spring wheat on fallow at Dickinson, expressed the regression contribution in terms of a correlation coefficient of 0.69. The comparable statistic when growing season precipitation is used as the dependent variable (table 6) was found to be 0.33. If the difference between these values reflects other than sampling error, the annual precipitation may be considered as a better indicator of the basic causative factors than is growing season precipitation.

TABLE 5.—*Dependence of spring wheat yield (y) on stored soil moisture (M) at the selected locations in the northern Great Plains*

Location and treatment	Years of record	Regressions ($y=a+bM$)	Standard error (s_e)	Standard error of b ($s(b)$)	$F_1 = \frac{RMST}{s_e^2}$	$F_2 = \frac{TMS}{s_e^2}$
Ardmore:						
Alternate fallow	17	$y = -47.361 + 5.129M$	11.565	2.340	4.804*	
Continuous cropping	17	$y = -22.768 + 3.354M$	11.420	1.220	9.494**	
Combined	17	$y = -28.268 \pm 1.427 + 3.741M$	11.393	1.076	12.066**	1.914
Newell:						
Alternate fallow	47	$y = -20.293 + 3.490M$	12.497	1.402	6.198*	
Continuous cropping	47	$y = -14.885 + 2.886M$	11.117	.979	8.684**	
Combined	47	$y = -16.521 \pm .668 + 3.116M$	11.770	.816	14.603**	11.193
Dickinson:						
Alternate fallow	22	$y = 17.136 + .697M$	9.666	1.353	.266	
Continuous cropping	22	$y = 3.774 + 1.579M$	9.726	1.428	1.221	
Combined	22	$y = 10.359 \pm 7.597 + 1.117M$	9.602	.973	1.318	9.221
Havre:						
Alternate fallow	31	$y = -15.589 + 3.501M$	9.526	1.460	5.751*	
Continuous cropping	31	$y = -8.588 + 2.604M$	6.425	.981	7.047*	
Combined	31	$y = -11.481 \pm .075 \pm 3.051M$	8.074	.873	12.206**	15.021
Huntley:						
Alternate fallow	34	$y = -19.915 + 3.790M$	9.523	.935	16.424**	
Continuous cropping	34	$y = -13.603 + 2.810M$	7.870	.842	11.154**	
Combined	34	$y = -16.830 \pm .916 + 3.342M$	8.709	.630	28.147**	7.037

† RM/S = Regression mean square.‡ TMS = Treatment mean square.

* = Significant at 5-percent level.

** = Significant at 1-percent level.

† Fall-plowed, other stations spring-plowed.

TABLE 6.—*Dependence of spring wheat yield (y) on seasonal precipitation (S) at the selected locations in the northern Great Plains*

Location and treatment	Years of record	Regressions ($y=a+bS$)	Standard error (s_e)	Standard error of b ($s(b)$)	$RMS\frac{\dagger}{s_e}$	$F_2=\frac{TMS\ddagger}{s_e^2}$
Ardmore:						
Alternate fallow-----	20	$y=-7.861+2.542S$	9.139	0.607	17.538**	
Continuous cropping-----	20	$y=-18.922+3.123S$	7.126	.473	43.546**	
Combined-----	20	$y=-13.392\pm 2.668+2.832S$	7.265	.341	68.947**	4.708*
Newell:						
Alternate fallow-----	47	$y=2.145+2.106S$	10.505	.402	27.456**	
Continuous cropping ¹ -----	47	$y=5.407+2.043S$	9.170	.351	33.902**	
Combined-----	47	$y=-1.631\pm 4.062+2.074S$	9.806	.265	61.135**	16.125**
Dickinson:						
Alternate fallow-----	51	$y=9.522+1.013S$	10.255	.421	5.780*	
Continuous cropping-----	51	$y=1.689+1.089S$	7.650	.314	12.017**	
Combined-----	51	$y=5.606\pm 3.554+1.051S$	9.002	.261	16.158**	15.895**
Havre:						
Alternate fallow-----	31	$y=-2.729+2.865S$	7.526	.555	26.688**	
Continuous cropping-----	31	$y=-7.814+2.422S$	3.749	.276	76.836**	
Combined-----	31	$y=-5.272\pm 3.974+2.644S$	5.921	.308	73.420**	27.935**
Huntley:						
Alternate fallow-----	34	$y=4.377+2.912S$	9.230	.658	19.558**	
Continuous cropping-----	34	$y=7.536+2.522S$	6.668	.476	28.116**	
Combined-----	34	$y=-5.956\pm 1.579+2.717S$	8.003	.404	45.292**	8.332**

† RMS =Regression mean square.
‡ TMS =Treatment mean square.
¹ Fall-plowed, others spring-plowed.

* = Significant at 5-percent level.
** = Significant at 1-percent level.

TABLE 7.—Multiple regression equations relating spring wheat yields (y) to stored soil moisture (M) and seasonal precipitation (S)

Location and treatment	Years of record	Regressions ($y = a + b_m M + b_s S$)	Standard errors		
			s_e	$s(b_m)$	$s(b_s)$
Ardmore:					
Alternate fallow	17	$y = -26.213 + 1.464M + 2.639S$	7.720	1.767	0.595
Continuous cropping	17	$y = -27.395 + .960M + 3.085S$	5.406	.665	.424
Combined	17	$y = -25.666 \pm 1.443 + 1.140M + 2.859S$	6.480	.691	.478
Newell:					
Alternate fallow	47	$y = -22.324 + 2.190M + 1.935S$	10.230	.402	.162
Continuous cropping ¹	47	$y = -16.425 + 1.335M + 1.829S$	9.027	.855	.371
Combined	47	$y = -19.639 \pm 2.264 + 1.650M + 1.878S$	9.566	.696	.260
Dickinson:					
Alternate fallow	22	$y = 6.504 + .894M + .944S$	9.454	1.331	.683
Continuous cropping	22	$y = -10.762 + 1.846M + 1.321S$	9.054	1.336	.654
Combined	22	$y = -2.254 \pm 3.674 + 1.350M + 1.133S$	9.066	.924	.461
Havre:					
Alternate fallow	31	$y = -26.312 + 2.758M + 2.689S$	6.877	1.063	.511
Continuous cropping	31	$y = -13.998 + 1.158M + 2.249S$	3.565	.573	.276
Combined	31	$y = -18.698 \pm 1.414 + 1.929M + 2.437S$	5.518	.612	.295
Huntley:					
Alternate fallow	34	$y = -22.187 + 2.549M + 2.127S$	8.372	.908	.659
Continuous cropping	34	$y = -19.894 + 1.877M + 2.161S$	6.064	.458	.204
Combined	34	$y = -21.101 \pm 1.522 + 2.232M + 2.159S$	7.217	.559	.390

¹ Fall-plowed, others spring-plowed.

The standard errors associated with the regressions of yield on growing season precipitation in table 6 are such as to suggest that the use of these equations for prediction of crop yields for a given year carries too large an uncertainty for them to be useful. To this end a regression model expressing yields as a function of both growing season precipitation and stored soil moisture is considered, and the resulting equations given in table 7. Some apparent improvement in the effectiveness of the regressions is suggested.

As was to be expected from the simple regressions exhibited in tables 5 and 6, the multiple regressions expressed in table 7 show in all cases a reduction in standard error of estimate over those previously examined. Hence, the combined model $y = a + b_m M + b_s S$ has stronger predictive power for providing estimates of the yield, as a result of the knowledge of growing season precipitation and preseasonal soil moisture measurement.

The relatively large percentage reduction in total sum of squares (table 8) associated with seasonal precipitation indicates that seasonal precipitation was more effective than stored soil moisture in determining yields. Comparison of the independent and combined effects

TABLE 8.—*Percent reduction of total sums of squares (SS) provided by regression equations of table 7*

Location and treatment	Reductions in regression (percentage of total SS) due to—				
	<i>M</i> alone	<i>S</i> after <i>M</i>	<i>S</i> alone	<i>M</i> after <i>S</i>	Treatment
Ardmore:					
Alternate fallow.....	24. 26	44. 24	66. 96	1. 54	
Continuous cropping.....	33. 49	52. 60	84. 02	2. 07	
Combined.....	26. 82	47. 34	72. 21	1. 96	4. 25
Newell:					
Alternate fallow.....	12. 11	30. 30	37. 89	4. 52	
Continuous cropping ¹	16. 18	29. 78	42. 97	2. 99	
Combined.....	12. 50	27. 01	36. 33	3. 18	9. 58
Dickinson:					
Alternate fallow.....	1. 31	6. 16	5. 65	1. 82	
Continuous cropping.....	5. 75	16. 67	14. 63	7. 79	
Combined.....	2. 56	10. 34	9. 21	3. 69	17. 89
Havre:					
Alternate fallow.....	16. 55	41. 46	47. 92	10. 09	
Continuous cropping.....	19. 55	56. 54	72. 60	3. 49	
Combined.....	30. 74	20. 43	45. 79	5. 38	17. 42
Huntley:					
Alternate fallow.....	33. 92	16. 60	37. 93	12. 58	
Continuous cropping.....	25. 85	31. 50	46. 77	10. 57	
Combined.....	28. 09	21. 01	38. 18	10. 92	7. 02

¹ Fall-plowed, others spring-plowed.

of soil moisture and seasonal precipitation in reducing the total sum of squares suggests that these sets of observations are interrelated. They could not be considered to be correlated in the strict sense, as the physical phenomena they represent must be considered to be independent.

There is, however, some evidence to suggest that rainfall amounts during selected periods should not be considered as truly random. If nature provides a correlation between the rainfall during any one period and that in the preceding or succeeding period, some relationship between soil moisture at seeding and growing season precipitation measurements would be expected.

Records of preseasonal precipitation (P) are available. It is to be expected that these observations would be correlated with soil moisture determinations. They could logically be considered as a causative factor leading to the soil moisture conditions. The estimates of these correlations are shown in table 9. A positive association is fairly well defined except perhaps at Ardmore and Dickinson. However, in no case is the order of association as high as might have been anticipated.

TABLE 9.—*Correlation between soil moisture at seeding and preseasonal precipitation*

Location and treatment	Years of record	Correlation estimate	Approximate 95 per cent confidence limits on correlation coefficients
Ardmore:			
Alternate fallow	16	0.384	$-0.139 < \rho < 0.739$
Continuous cropping	17	.345	$-.163 < \rho < .708$
Newell:			
Alternate fallow	47	.595	$.368 < \rho < .755$
Continuous cropping ¹	47	.418	$.147 < \rho < .632$
Dickinson:			
Alternate fallow	20	.232	$-.236 < \rho < .604$
Continuous cropping	21	.359	$-.087 < \rho < .680$
Havre:			
Alternate fallow	30	.596	$.301 < \rho < .787$
Continuous cropping	31	.560	$.257 < \rho < .761$
Huntley:			
Alternate fallow	34	.510	$.209 < \rho < .723$
Continuous cropping	34	.670	$.430 < \rho < .822$

¹ Fall-plowed, others spring-plowed.

This investigation of correlation leads one to consider a model in which yield is expressed as a function of growing season precipitation (S) and preseasonal precipitation (P). The regression equations developed from fitting this model are shown in table 10. It may be

observed that in general there is no appreciable change in standard errors from those recorded in table 7 for the model expressing yield as a function of seasonal precipitation and soil moisture at seeding. However, in the case of Dickinson, there is an indication of considerable improvement, which would seem to suggest some anomaly there in the reflection of soil moisture measurements to the prediction of yield.

TABLE 10.—*Multiple regression equations relating spring wheat yields (y) to seasonal precipitation (S) and preseasonal precipitation (P)*

Location and treatment	Years of record	Regressions ($y = A + B_s S + C_P P$)	Standard error (s_e)
Ardmore:			
Alternate fallow-----	19	$y = -25.91 + 2.59S + 0.78P$	8.9
Continuous cropping----	20	$y = -41.47 + 3.33S + 3.28P$	4.7
Newell:			
Alternate fallow-----	47	$y = -23.85 + 2.26S + 1.09P$	9.1
Continuous cropping ¹ ----	47	$y = -15.50 + 2.18S + 1.32P$	8.8
Dickinson:			
Alternate fallow-----	49	$y = -15.85 + .95S + 1.16P$	8.4
Continuous cropping----	50	$y = -5.95 + 1.03S + 1.22P$	6.8
Havre:			
Alternate fallow-----	30	$y = -22.29 + 2.84S + 1.16P$	6.9
Continuous cropping----	31	$y = -11.30 + 2.49S + .59P$	3.7
Huntley:			
Alternate fallow-----	34	$y = -41.14 + 3.00S + .64P$	9.1
Continuous cropping----	34	$y = -17.57 + 2.63S + 1.34P$	6.0

¹ Fall-plowed, others spring-plowed.

The regression equations showing wheat yields as a function of soil moisture and seasonal precipitation (table 7) or of seasonal and preseasonal precipitation (table 10) may be used for evaluating the range of yields that can be expected on given soil types under specific moisture conditions and for predicting crop yields. However, the predictive power of the regression equations is not strong.

Graphical representations of the regression surfaces of table 7 are shown in figure 1. A given yield may be obtained with different combinations of seasonal precipitation and soil moisture. For example, with continuous cropping at Ardmore, yields may range from 0 to 11.2 bushels per acre within the soil moisture and seasonal precipitation limits of 0 to 12 inches and 5.2 and 8.8 inches, respectively. Similarly, yields for alternate fallow at Ardmore may range from 0 to 17.7 bushels within the respective soil moisture and seasonal precipitation boundaries of 0 to 12 inches and 3.4 to 9.8 inches. This may be associated with rainfall distribution and stage of plant development. Army and Hanson (1) reported that precipitation

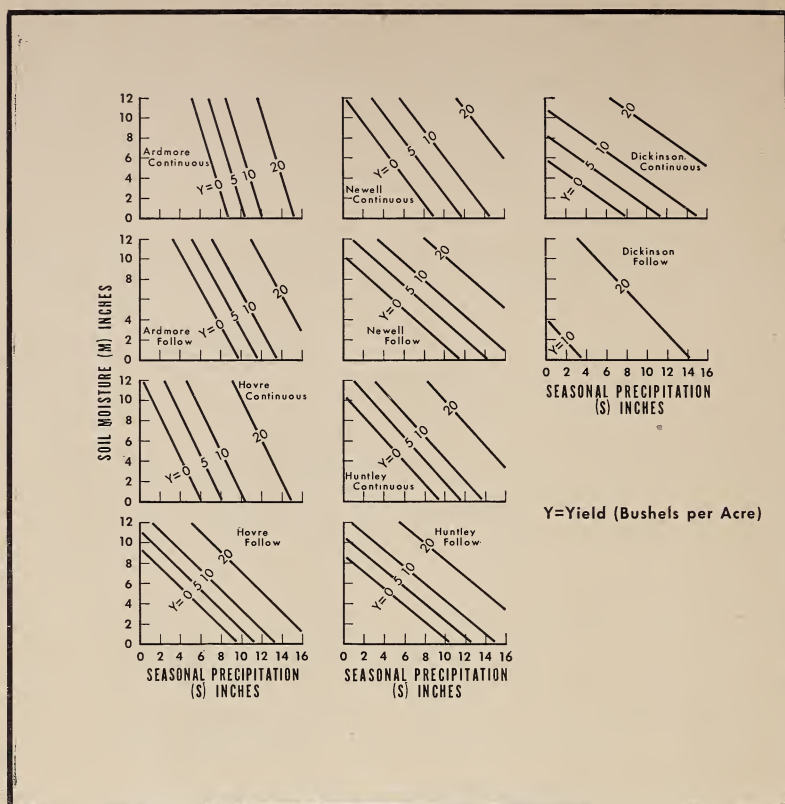


FIGURE 1.—Relationship of yield (Y) to seasonal precipitation (S) and soil moisture supply (M) at seeding on alternate fallow and continuously cropped spring wheat.

between seeding and heading was more critical in relation to yield than precipitation in the remainder of the growing season.

Figure 2 exhibits the character of the regression equations expressing yield as a function of seasonal precipitation and preseasonal precipitation that were presented in table 10. For example, all yields from 0 to 23.9 bushels per acre are probable on alternate fallow at Newell if the respective seasonal and preseasonal precipitation values range from 0 to 10.6 inches and from 10 to 21.8 inches.

Within the limits of the information being evaluated, the regression equations (table 7) could be used for predictive purposes. For example, the surface for continuous cropping at Ardmore would give an estimated yield of 8 bushels per acre for 5 inches of soil moisture and 10 inches of seasonal precipitation. The standard error can be

used in assigning confidence limits to this estimate. In this case the 95 percent confidence limits predict a yield between 0 and 22 bushels per acre. Similarly, the predicted yield for alternate fallow at Ardmore would be between 0 and 28 bushels per acre.

As an example of the kind of predictions that might be provided by the equations of table 10, a selection of 5 inches for preseasonal precipitation (P) and 10 for seasonal precipitation (S) for continuous

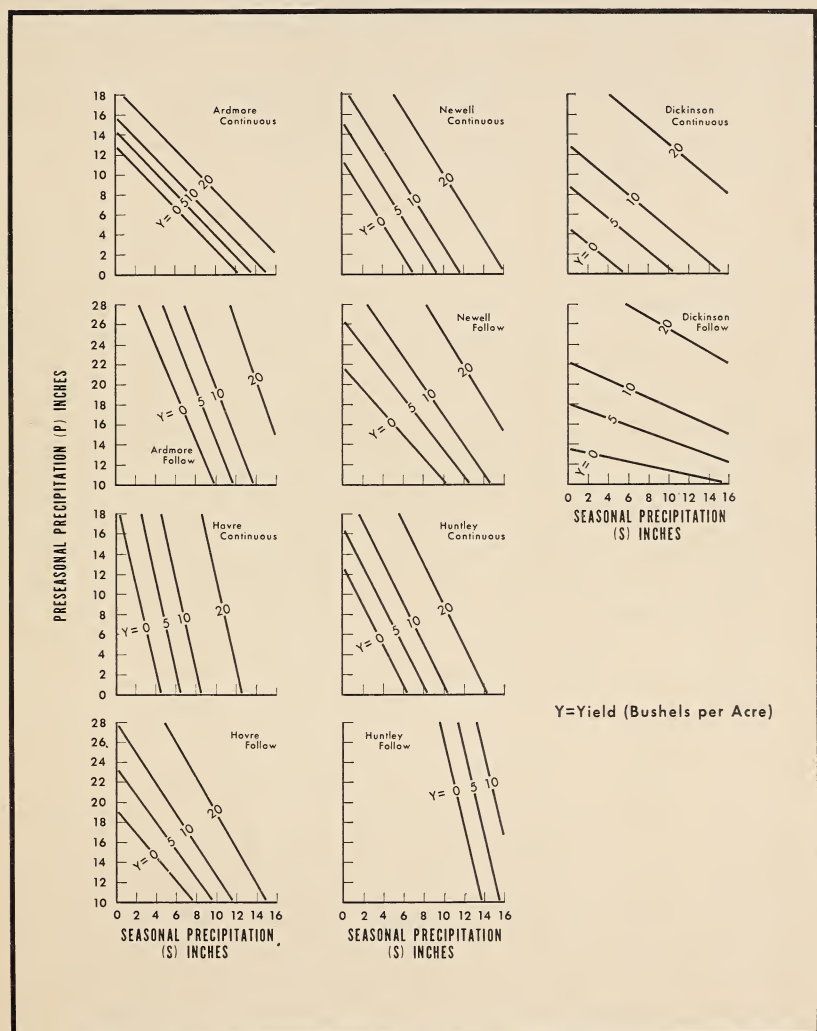


FIGURE 2.—Relationship of yield (Y) to seasonal precipitation (S) and preseasonal precipitation (P) on alternate fallow and continuously cropped spring wheat.

cropping at Ardmore will give a predicted yield of 8 bushels per acre with 95 percent confidence of 0 to 20 bushels; for alternate fallow a predicted yield of 12 bushels per acre will be between 0 and 36 bushels per acre.

Extraneous factors, as insects and hail, were not compensated for or included in any of these regression studies. When one considers that no crop data were excluded in the study for any reason, more value can be placed on the conclusions than is perhaps apparent from the regression studies. The relationships shown with their rather large standard errors are truly indicative of the actual variability in spring wheat yields on selected soil types under specific moisture conditions. Use of these regression equations for prediction purposes during any given year definitely has limitations and requires caution and good judgment.

SUMMARY

The premise that the levels of soil moisture at seeding, growing season precipitation, and preseasonal precipitation are reflected in the spring wheat yields observed was investigated by the use of linear and multiple regression on data from several locations in the northern Great Plains.

Stored soil moisture, although providing linear regressions with significant coefficients at most locations, did not sufficiently reduce the estimates of error variability to make predictive estimates practicable.

The model expressing yield as a function of growing season precipitation seemed to be more effective in reducing the error estimates. Hence, the predictions from growing season precipitation data were sharper than those from the stored soil moisture data, although there was considerable difference from location to location.

The use of both soil moisture and seasonal precipitation in a multiple regression model further reduced the error estimates and made this the best predictor for the data available.

The correlations between preseasonal precipitation and soil moisture at seeding were not so high as anticipated. Nevertheless, the regression model of yield on preseasonal and seasonal precipitation seemed almost as effective as that on seasonal precipitation and soil moisture at seeding.

The standard errors for the regressions of yield on soil moisture and seasonal precipitation ranged from 3.6 to 10.2 bushels per acre, and those for yield on preseasonal and seasonal precipitations ranged from 3.7 to 9.1 bushels per acre.

Some indication of the use of the multiple regression functions to define the yield range under specific moisture conditions and as predictive equations is demonstrated.

LITERATURE CITED

- (1) ARMY, T. J., and HANSON, W. D.
1960. MOISTURE AND TEMPERATURE INFLUENCES ON SPRING WHEAT PRODUCTION IN THE PLAINS AREA OF MONTANA. U.S. Dept. Agr. Prod. Res. Rpt. 34, 25 pp., illus.
- (2) CHILCOTT, E. C.
1927. THE RELATIONS BETWEEN CROP YIELDS AND PRECIPITATION IN THE GREAT PLAINS AREA. U.S. Dept. Agr. Misc. Cir. 81, 94 pp., illus.
- (3) COLE, J. S.
1938. CORRELATIONS BETWEEN ANNUAL PRECIPITATION AND YIELD OF SPRING WHEAT IN THE GREAT PLAINS. U.S. Dept. Agr. Tech. Bul. 636, 39 pp.
- (4) ——— and MATHEWS, O. R.
1940. RELATION OF THE DEPTH TO WHICH THE SOIL IS WET AT SEEDING TIME TO THE YIELD OF SPRING WHEAT ON THE GREAT PLAINS. U.S. Dept. Agr. Cir. 563, 19 pp.
- (5) FINNELL, H. H.
1948. SOIL MOISTURE AND WHEAT YIELDS ON THE HIGH PLAINS. U.S. Dept. Agr. Leaf. 247, 8 pp., illus.
- (6) HAAS, H. J., and EVANS, C. E.
1957. NITROGEN AND CARBON CHANGES IN GREAT PLAINS SOILS AS INFLUENCED BY CROPPING AND SOIL TREATMENTS. U.S. Dept. Agr. Tech. Bul. 1164, 111 pp.
- (7) OSENBRUG, A., and MATHEWS, O. R.
1951. DRYLAND CROP PRODUCTION ON THE CLAY SOILS OF WESTERN SOUTH DAKOTA. S. Dak. Agr. Expt. Sta. Cir. 85, 22 pp.
- (8) PENGRA, R. F.
1952. ESTIMATING CROP YIELDS AT SEEDING TIME IN THE GREAT PLAINS. Amer. Soc. Agron. Jour. 44: 271-274, illus.
- (9) SALMON, S. C., MATHEWS, O. R., and LEUKEL, R. W.
1953. A HALF CENTURY OF WHEAT IMPROVEMENT IN THE UNITED STATES. Advances in Agronomy 5: 1-151.
- (10) SNEDECOR, G. W.
1946. STATISTICAL METHODS. Ed. 4, pp. 103-168, 340-373. Iowa State College Press, Ames, Iowa.
- (11) THYSELL, J. C.
1938. CONSERVATION AND USE OF SOIL MOISTURE AT MANDAN, NORTH DAKOTA. U.S. Dept. Agr. Tech. Bul. 617, 40 pp.
- (12) UNITED STATES DEPARTMENT OF AGRICULTURE.
1941. CLIMATES OF THE STATES. In Climate and Man, U.S. Dept. Agr. Yearbook 1941, pp. 749-1210.

APPENDIX

TABLE 11.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for fallowed plots at Ardmore, S. Dak.*

Year	Yield per acre	Precipitation		Soil moisture
		Pre- seasonal Aug. 2- Apr. 4 ¹	Seasonal Apr. 5- Aug. 1	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1913.....	7.2	-----	6.92	10.68
1914.....	0	18.73	8.24	11.53
1915.....	45.0	21.17	20.04	13.28
1916.....	15.8	36.21	8.85	14.06
1917.....	8.7	23.15	10.26	14.03
1918.....	37.0	21.75	12.87	13.39
1919.....	10.3	25.92	9.72	12.27
1920.....	23.7	21.89	12.71	13.24
1921.....	17.7	23.70	8.73	-----
1922.....	0	17.39	12.47	-----
1923.....	21.0	20.92	11.50	-----
1924.....	15.2	24.43	6.00	10.79
1925.....	16.3	19.72	9.46	13.72
1926.....	11.8	21.53	8.25	11.78
1927.....	37.2	23.31	13.91	14.92
1928.....	32.2	29.20	9.09	13.64
1929.....	17.8	18.97	8.70	11.23
1930.....	10.7	18.28	6.76	12.21
1931.....	2.5	22.11	3.90	13.21
1932.....	13.3	18.45	8.60	12.42
Mean.....	17.2	22.46	9.85	12.73

¹ Includes fallow year.

TABLE 12.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for spring-plowed continuous-cropped plots at Ardmore, S. Dak.*

Year	Yield per acre	Precipitation		Soil moisture
		Pre- seasonal Aug. 2- Apr. 4	Seasonal Apr. 5- Aug. 1	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1913.....	2.3	5.69	6.92	5.56
1914.....	0	6.12	8.24	8.72
1915.....	49.2	6.81	20.04	11.78
1916.....	18.0	9.36	8.85	13.48
1917.....	7.5	4.94	10.26	13.33
1918.....	27.7	6.55	12.87	10.64
1919.....	3.3	6.50	9.72	10.13
1920.....	23.8	5.67	12.71	14.54
1921.....	7.7	5.32	8.73	-----
1922.....	0	3.34	12.47	-----
1923.....	16.2	5.11	11.60	-----
1924.....	6.0	7.82	6.00	9.49
1925.....	7.3	5.90	9.46	8.28
1926.....	5.7	6.17	8.25	10.64
1927.....	33.5	8.89	13.91	14.12
1928.....	9.5	6.40	9.09	10.07
1929.....	5.7	3.48	8.70	8.54
1930.....	3.8	6.10	6.76	10.38
1931.....	1.0	9.25	3.90	9.90
1932.....	8.5	5.30	8.60	9.26
Mean.....	11.8	6.24	9.85	10.52

TABLE 13.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture on fallowed plots at Newell, S. Dak.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 2– Apr. 10 ¹	Seasonal Apr. 11– Aug. 1	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1909.....	32.2	21.68	12.68	11.94
1910.....	5.0	24.27	5.78	12.33
1911.....	0	17.13	2.23	10.02
1912.....	0	12.20	8.20	9.58
1913.....	16.8	22.22	5.47	12.56
1914.....	15.8	20.47	6.74	11.05
1915.....	57.2	19.20	15.26	9.41
1916.....	18.7	26.29	7.98	13.01
1917.....	11.1	19.41	7.14	11.52
1918.....	35.0	19.88	8.29	12.11
1919.....	6.2	24.32	5.09	10.98
1920.....	29.2	24.10	18.97	14.54
1921.....	25.0	33.76	7.89	11.36
1922.....	31.5	19.55	14.56	13.12
1923.....	31.0	26.50	11.13	12.61
1924.....	23.8	34.10	3.60	12.13
1925.....	24.5	30.30	5.76	12.88
1926.....	45.2	21.08	11.16	12.54
1927.....	25.5	23.80	16.85	13.86
1928.....	41.7	29.45	10.53	12.39
1929.....	29.7	23.51	11.63	13.44
1930.....	11.0	27.52	7.02	13.35
1931.....	0.8	21.23	4.75	12.27
1932.....	18.8	14.37	13.48	9.73
1933.....	19.8	23.44	13.33	13.23
1934.....	21.3	26.27	5.82	12.86
1935.....	10.5	19.83	6.97	11.93
1936.....	1.0	19.33	3.93	11.71
1937.....	18.7	15.22	11.59	9.71
1938.....	15.3	23.78	5.66	11.91
1939.....	0	15.47	5.37	9.28
1940.....	0	15.12	10.27	8.24
1941.....	24.0	21.28	13.72	12.27
1942.....	42.3	26.57	13.96	13.52
1943.....	29.7	28.16	7.41	12.18
1944.....	35.0	19.80	10.87	11.41
1945.....	19.8	24.62	7.10	11.94
1946.....	34.7	21.54	16.37	11.67
1947.....	27.5	34.45	7.39	12.80
1948.....	39.2	24.63	11.39	12.67
1949.....	15.7	23.47	6.47	12.67
1950.....	21.8	19.16	5.76	11.69
1951.....	21.5	19.45	7.19	10.61
1952.....	12.8	22.62	6.58	10.81
1953.....	20.1	19.46	10.03	12.81
1954.....	13.1	20.96	7.83	11.70
1955.....	15.0	19.69	7.14	11.85
Mean.....	21.2	22.60	9.03	11.88

¹ Includes fallow year.

TABLE 14.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding on fall-plowed continuous-cropped plots at Newell, S. Dak.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 2- Apr. 10	Seasonal Apr. 11- Aug. 1	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1909.....	23.3	4.94	12.68	7.62
1910.....	0	6.65	5.78	11.37
1911.....	0	4.70	2.23	9.02
1912.....	0	5.27	8.20	9.70
1913.....	7.9	8.75	5.47	9.07
1914.....	4.8	6.25	6.74	7.67
1915.....	57.7	6.21	15.26	9.26
1916.....	10.8	4.82	7.98	7.76
1917.....	2.8	6.61	7.14	8.18
1918.....	9.8	6.13	8.29	8.49
1919.....	0	9.90	5.09	8.12
1920.....	28.7	9.11	18.97	13.66
1921.....	2.0	5.68	7.89	6.51
1922.....	30.0	5.98	14.56	11.19
1923.....	28.5	5.96	11.13	11.86
1924.....	19.5	17.01	3.60	12.07
1925.....	15.2	9.69	5.76	10.50
1926.....	29.3	5.63	11.16	9.20
1927.....	12.3	7.01	16.85	13.20
1928.....	26.2	5.59	10.53	9.31
1929.....	23.5	7.39	11.63	11.23
1930.....	6.7	8.50	7.02	11.26
1931.....	0	5.71	4.75	7.90
1932.....	15.5	3.91	13.48	8.98
1933.....	14.5	6.05	13.33	12.01
1934.....	10.7	6.89	5.82	8.66
1935.....	2.8	7.12	6.97	9.84
1936.....	0	5.24	3.93	8.66
1937.....	5.3	6.05	11.59	7.83
1938.....	6.2	6.14	5.66	9.15
1939.....	0	3.67	5.37	6.51
1940.....	0	6.08	10.27	8.52
1941.....	17.3	4.93	13.72	10.68
1942.....	34.0	7.92	13.96	10.67
1943.....	7.7	6.28	7.41	8.25
1944.....	29.2	6.11	10.87	10.26
1945.....	15.2	7.64	7.10	9.43
1946.....	18.5	6.80	16.37	9.03
1947.....	21.2	11.28	7.39	12.68
1948.....	21.0	5.96	11.35	10.67
1949.....	9.3	6.12	6.47	11.41
1950.....	11.3	6.57	5.76	10.55
1951.....	3.2	7.12	7.19	8.21
1952.....	2.7	8.31	6.58	9.18
1953.....	14.1	4.57	10.03	11.19
1954.....	7.0	6.36	7.83	10.13
1955.....	7.0	5.50	7.14	9.19
Mean.....	13.0	6.73	9.03	9.70

TABLE 15.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for fallowed plots at Dickinson, N. Dak.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 9- Apr. 11 ¹	Seasonal Apr. 12- Aug. 8	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1907.....	28.3	-----	9.73	5.39
1908.....	33.8	-----	9.64	7.33
1909.....	35.7	23.03	12.24	7.48
1910.....	26.8	30.10	8.66	7.47
1911.....	23.3	23.49	6.86	7.66
1912.....	0	18.32	11.95	8.12
1913.....	27.0	26.60	5.46	8.70
1914.....	21.1	19.53	16.91	7.35
1915.....	38.7	27.77	14.45	6.79
1916.....	22.8	26.14	13.00	7.62
1917.....	12.3	25.10	5.24	7.47
1918.....	19.5	13.74	6.93	-----
1919.....	5.3	17.06	4.11	-----
1920.....	21.1	13.77	9.24	-----
1921.....	5.7	19.56	7.19	4.44
1922.....	27.6	23.08	11.53	6.40
1923.....	14.8	25.80	12.14	6.07
1924.....	27.0	25.61	8.55	7.75
1925.....	20.0	22.74	7.77	6.42
1926.....	11.0	18.76	6.59	4.67
1927.....	22.3	18.55	11.81	5.39
1928.....	29.2	26.16	10.42	6.12
1929.....	15.3	25.27	7.06	-----
1930.....	20.0	22.48	7.24	11.88
1931.....	2.5	21.03	9.23	-----
1932.....	24.2	21.85	10.81	8.03
1933.....	14.3	23.89	7.02	7.64
1934.....	8.0	17.77	5.36	-----
1935.....	11.5	12.67	10.37	-----
1936.....	0	17.60	2.00	-----
1937.....	5.3	11.03	11.51	-----
1938.....	7.7	21.23	11.75	-----
1939.....	26.7	20.82	11.80	-----
1940.....	14.3	20.43	10.44	-----
1941.....	17.0	21.15	20.64	-----
1942.....	48.0	37.48	13.33	-----
1943.....	19.5	30.52	8.43	-----
1944.....	39.5	20.85	11.60	-----
1945.....	26.7	29.48	6.18	-----
1946.....	27.0	21.27	7.08	-----
1947.....	18.5	17.88	13.50	-----
1948.....	34.5	26.90	10.51	-----
1949.....	7.2	20.90	5.41	-----
1950.....	17.5	16.43	6.79	-----
1951.....	22.2	19.41	7.54	-----
1952.....	8.2	23.58	6.55	-----
1953.....	21.2	22.12	13.16	-----
1954.....	10.3	25.72	6.71	-----
1955.....	20.7	21.60	10.07	-----
1956.....	7.2	22.56	7.32	-----
1957.....	7.8	16.55	14.53	-----
Mean.....	19.1	21.95	9.50	7.10

¹ Includes fallow year.

TABLE 16.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for spring-plowed continuous-cropped plots at Dickinson, N. Dak.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 9– Apr. 11	Seasonal Apr. 12– Aug. 8	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1907	37.0		9.73	7.71
1908	24.3	5.93	9.64	5.87
1909	26.8	7.46	12.24	5.57
1910	17.4	10.40	8.66	6.46
1911	5.7	4.43	6.86	5.41
1912	0	7.03	11.95	6.69
1913	13.5	7.62	5.46	7.29
1914	10.5	6.45	16.91	4.85
1915	25.8	4.41	14.45	4.69
1916	16.7	7.28	13.00	7.59
1917	5.5	4.82	5.24	6.19
1918	3.5	3.68	6.93	
1919	0	6.45	4.11	
1920	15.6	3.21	9.24	
1921	3.9	7.11	7.19	3.42
1922	23.5	8.78	11.53	5.44
1923	10.3	5.49	12.14	6.79
1924	18.0	7.98	8.55	7.79
1925	4.5	6.21	7.77	5.78
1926	0	4.78	6.59	3.21
1927	11.8	7.18	11.81	4.84
1928	12.5	7.17	10.42	5.27
1929	10.2	7.78	7.06	
1930	7.3	7.64	7.24	9.70
1931	1.0	6.15	9.23	
1932	15.7	6.47	10.81	6.66
1933	1.8	6.61	7.02	5.45
1934	1.3	4.14	5.36	
1935	13.5	3.17	10.37	
1936	0	4.06	2.00	
1937	10.0	4.97	11.51	
1938	4.3	4.75	11.75	
1939	17.0	4.32	11.80	
1940	8.7	4.31	10.44	
1941	12.3	6.40	20.64	
1942	28.7	10.44	13.33	
1943	17.8	6.75	8.43	
1944	20.2	5.67	11.60	
1945	13.2	12.21	6.18	
1946	9.3	2.88	7.08	
1947	15.0	7.92	13.50	
1948	21.7	5.48	10.51	
1949	3.2	4.91	5.41	
1950	14.5	6.11	6.79	
1951	13.7	6.51	7.54	
1952	7.5	9.53	6.55	
1953	15.8	6.04	13.16	
1954	9.0	6.52	6.71	
1955	21.5	8.37	10.07	
1956	2.1	4.12	7.32	
1957	10.5	5.11	14.53	
Mean	12.0	6.26	9.50	6.03

TABLE 17.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for fallowed plots at Havre, Mont.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 9– Apr. 18 ¹	Seasonal Apr. 19– Aug. 8	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1917.....	11.7		3.32	11.0
1918.....	5.8	17.06	2.98	10.2
1919.....	2.2	17.81	3.72	7.6
1920.....	10.5	13.89	6.33	8.6
1921.....	19.0	15.67	8.01	9.1
1922.....	12.2	17.73	6.60	9.2
1923.....	20.0	14.52	11.25	8.1
1924.....	18.0	19.63	8.22	9.0
1925.....	18.5	17.67	9.17	8.5
1926.....	13.5	21.05	3.21	9.8
1927.....	37.7	18.50	12.57	11.7
1928.....	41.3	24.59	7.77	9.7
1929.....	15.7	17.15	6.80	9.9
1930.....	11.3	17.04	3.99	10.2
1931.....	3.0	14.03	5.49	8.1
1932.....	27.2	13.45	9.21	8.2
1933.....	12.8	17.90	6.07	10.4
1934.....	.5	20.77	4.16	8.1
1935.....	13.2	18.47	4.93	9.9
1936.....	.3	13.06	3.20	8.4
1937.....	5.5	9.94	7.07	6.3
1938.....	22.7	16.27	9.39	8.5
1939.....	9.8	19.02	7.11	8.4
1940.....	10.8	16.44	6.33	8.0
1941.....	19.3	16.83	5.86	9.2
1942.....	24.2	18.39	9.25	10.4
1943.....	31.3	20.80	8.84	9.9
1944.....	31.2	15.91	6.39	8.5
1945.....	9.0	13.11	4.42	7.1
1946.....	16.7	13.89	4.30	7.7
1947.....	13.7	15.20	4.45	8.2
Mean.....	15.8	16.86	6.46	9.0

¹ Includes fallow year.

TABLE 18.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for spring-plowed continuous-cropped plots at Havre, Mont.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 9- Apr. 18	Seasonal Apr. 19- Aug. 8	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1917.....	3.5	4.68	3.32	5.33
1918.....	5.7	9.06	2.98	7.68
1919.....	1.5	5.77	3.72	5.72
1920.....	7.2	4.40	6.33	6.58
1921.....	9.7	4.94	8.01	6.40
1922.....	7.2	4.78	6.60	7.20
1923.....	16.7	3.14	11.25	6.30
1924.....	11.8	5.24	8.22	6.20
1925.....	16.3	4.45	9.17	5.90
1926.....	4.3	7.43	3.21	7.20
1927.....	26.2	7.86	12.57	10.10
1928.....	16.0	4.16	7.77	6.90
1929.....	8.4	5.22	6.80	7.10
1930.....	2.2	5.02	3.99	7.00
1931.....	.8	5.02	5.49	5.50
1932.....	21.7	2.92	9.21	5.50
1933.....	.8	5.75	6.07	5.60
1934.....	.2	8.95	4.16	7.47
1935.....	4.2	5.36	4.93	7.10
1936.....	0	2.77	3.20	5.60
1937.....	1.2	3.97	7.07	4.90
1938.....	13.2	5.23	9.39	6.60
1939.....	1.7	4.40	7.11	5.10
1940.....	6.2	4.95	6.33	7.50
1941.....	4.0	5.55	5.86	5.70
1942.....	19.2	6.98	9.25	7.70
1943.....	16.0	4.57	8.84	6.10
1944.....	6.3	2.50	6.39	5.10
1945.....	2.8	4.22	4.42	5.80
1946.....	3.0	5.25	4.30	5.13
1947.....	5.2	5.65	4.45	3.60
Mean.....	7.8	5.17	6.46	6.31

TABLE 19.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for fallowed plots at Huntley, Mont.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 2- Apr. 11 ¹	Seasonal Apr. 12- Aug. 1	
	<i>Pushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1913.....	22.7	22.27	4.70	10.59
1914.....	19.5	20.89	7.03	12.13
1915.....	36.5	19.58	11.80	9.26
1916.....	13.5	23.75	6.76	7.86
1917.....	11.3	20.99	6.67	10.87
1918.....	18.8	24.16	5.03	10.65
1919.....	.7	20.47	2.32	7.43
1920.....	6.8	20.54	8.29	10.22
1921.....	17.7	24.49	7.19	9.12
1922.....	19.3	19.47	10.72	8.85
1923.....	10.3	24.02	8.75	9.27
1924.....	21.8	25.97	6.35	11.29
1925.....	10.0	24.75	5.89	10.02
1926.....	1.5	18.16	5.05	7.36
1927.....	20.3	18.26	10.76	8.95
1928.....	20.5	30.07	4.70	10.07
1929.....	9.7	25.54	3.65	8.83
1930.....	0	19.32	4.79	7.98
1931.....	0	18.05	1.39	5.47
1932.....	2.7	15.24	6.79	6.61
1933.....	.5	20.59	4.87	6.83
1934.....	4.5	20.14	2.22	6.60
1935.....	2.5	18.13	5.61	8.44
1936.....	.2	18.41	4.24	6.92
1937.....	5.5	13.97	3.81	5.47
1938.....	28.8	14.42	8.87	7.72
1939.....	12.3	20.76	8.08	8.99
1940.....	10.8	18.11	5.57	9.79
1941.....	2.5	14.36	6.45	8.59
1942.....	23.3	21.99	7.79	12.63
1943.....	31.7	24.77	6.59	11.16
1944.....	47.5	15.89	9.76	10.23
1945.....	20.3	18.57	6.26	9.13
1946.....	18.3	17.43	4.56	7.91
Mean.....	13.9	20.40	6.27	8.92

¹ Includes fallow year.

TABLE 20.—*Spring wheat yield, precipitation by climatological weeks, and soil moisture at seeding for spring-plowed continuous-cropped plots at Huntley, Mont.*

Year	Yield per acre	Precipitation		Soil moisture
		Preseasonal Aug. 2- Apr. 11	Seasonal Apr. 12- Aug. 1	
	<i>Bushels</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1913.....	16.0	8.92	4.70	8.85
1914.....	18.3	7.27	7.03	7.67
1915.....	24.5	5.28	11.80	6.71
1916.....	5.8	6.67	6.76	7.11
1917.....	7.8	8.46	6.67	11.81
1918.....	1.5	9.03	5.03	7.82
1919.....	0	6.41	2.32	6.60
1920.....	8.2	11.81	8.29	10.04
1921.....	3.0	4.39	7.19	5.76
1922.....	20.7	7.89	10.72	8.22
1923.....	6.3	5.16	8.75	7.71
1924.....	26.7	11.81	6.35	11.51
1925.....	7.0	6.59	5.89	6.97
1926.....	0	5.68	5.05	7.76
1927.....	24.2	7.53	10.76	8.47
1928.....	3.8	11.78	4.70	7.68
1929.....	2.8	9.06	3.65	7.35
1930.....	0	6.61	4.79	7.22
1931.....	0	6.65	1.39	5.59
1932.....	2.3	7.20	6.79	7.40
1933.....	0	6.60	4.87	6.58
1934.....	0	8.67	2.22	7.54
1935.....	1.0	7.33	5.61	7.94
1936.....	0	5.47	4.24	5.87
1937.....	2.0	4.26	3.81	6.13
1938.....	30.3	6.35	8.87	7.74
1939.....	7.5	5.54	8.08	7.78
1940.....	4.3	4.49	5.57	6.90
1941.....	5.0	4.30	6.45	7.97
1942.....	23.5	11.24	7.79	12.94
1943.....	9.0	5.74	6.59	8.12
1944.....	9.0	3.56	9.76	7.82
1945.....	5.8	5.25	6.26	6.81
1946.....	5.5	5.92	4.56	6.99
Mean.....	8.3	7.03	6.27	7.79

